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Discussed in this compilation of papers related to science teaching at the college level are (1) the crises in higher education and the need for more effective instruction, (2) the place of computers in undergraduate science education, (3) television and student involvement in science, (4) man in the Twentieth Century, and (5) challenges for the colleges and universities. The papers present insights into many of the issues confronting science education at the college level and give outlines of what has been attempted in some small colleges. (GR)

A COMPILATION OF PAPERS RELATED TO

SCIENCE TEACHING AT THE COLLEGE LEVEL

NATIONAL SCIENCE TEACHERS ASSOCIATION

WASHINGTON, D.C.

A Compilation of Papers Related to

SCIENCE TEACHING AT THE COLLEGE LEVEL

1968

National Science Teachers Association

1201 Sixteenth Street, N.W., Washington, D.C. 20036

FOREWORD

This compilation of papers related to science teaching at the college level was solicited and assembled by John E. Butler, Associate Professor of Biology, Humboldt State College, Arcata, California. Dr. Butler produced also the report* of four college level conferences on scientific literacy held during the 1967-68 academic year, sponsored by the NSTA College Activities Committee, and has worked closely with the Committee.

These papers are sent to all college science teachers who have expressed interest in being kept informed of NSTA college related activities.

October 1968

*"Steps Toward Scientific Literacy--A Report of College Level Conferences for Non-Science Majors" 1967-68, Special Publication, National Science Teachers Association, Washington, D. C. 1968.

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A CRISIS IN HIGHER EDUCATION:

THE NEED FOR MORE EFFECTIVE INSTRUCTION

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It is readily apparent by those of us involved in higher education that we are presently confronted with a very serious problem, namely, the need for more effective instruction. This problem is increasing in amplification as a result of the "Explosive Pinch" the impact of an exploding population from one side, and the pressure of a knowledge explosion from the other. Never before in the history of education have we, as instructors, been subjected to such a crucial test. There is far too much to be learned, too many students per instructor, and far too little time in which to relay to the student all that he might have anticipated as a result of his years spent on campus. We must, therefore, seek out and exploit any and all means of training students in the skills of educating themselves. This need, the ability to self-educate, is even more pressing when we consider the student who terminates his stay at college at the end of one year or two, for education is never terminal.

Impossible as this task may seem, each of us must address himself to its challenge. We must take a firm stand and look at this problem squarely in the face and, more importantly, provide a very <u>real</u> and <u>specific</u> plan of attack. As is true with any test of ability we must have confidence in our plan, and this confidence must have its foundation in those two factors; realism and specifics.

Realism in any educational process is a dependent quality, dependent upon the ability of the students, the resources of the institution, and the current demands of society. It is not surprising, therefore, to note a variation of educational philosophy from school to school and even within the same school with the passage of time.

The second item, specificity, is quite independent in character and is, or should be, common to <u>all</u> levels of education. The tool of educational specificity is precise written and oral communications. <u>The art of effective teaching demands that one cultivate the ability to communicate explicitly</u>. Communication in education is trichotomous in nature. The successful teacher must be capable of relating, quite clearly, ideas and processes to his students, his colleagues, and most importantly to himself. Self-communication is so continuous and intimate that it is often the last thing we suspect in our inability to communicate with others.

At a meeting I attended recently an idea was expressed that has bothered me considerably. It was said that if a businessman were to operate in a manner similar to the way that many of us perform as instructors, he would soon be out of the running. We could argue the impropriety and irrelevancy of such a comparison, but in so doing we could very well be missing the actual intended criticism.

This criticism, I believe, stems from the fact that the successful businessman depends quite heavily upon his ability to organize and continuously evaluate his efforts and/or products. Herein lies the weakness of many of us as educators. In our sincere attempt to implement realism and be more specific in our instruction we tend to become lax when it comes to organization and evaluation. If we might consider, for a moment, the student as a product and our instruction as a production process, then the above mentioned criticism becomes more meaningful.

Until we are willing to structure our teaching so as to include steps for student development and means by which we can evaluate these steps, we shall never be certain of the learner's growth and our effectiveness. As does industry, educators must commit themselves to the use of a "quality control" with reference to the students with which they come in contact. To bring about this ability to self-educate, we should first recognize it as an extension of the student's learning pattern.

To nurture a viable learning pattern, we start by identifying recognizable changes of the learner's behavior; his ability to cope with a situation which he was previously unable to handle. In academic disciplines which tend to be highly cognitive, such as science and mathematics, the task of formulating a hierarchical listing of desired changes on the part of the student is somewhat simpler contrasted to those areas of study where a large portion of the learning abounds within the affective domain.

If we would sit down and ask ourselves, "What should my students be able to do upon completing my course that they were unable to do prior to that time?" then we would have taken the first step in this quality control idea. The second step would, of course, be to write in specific terms the measurable interim behavioral changes required to achieve the over-all growth which the instructor anticipated for the student. It is a new twist to an old idea, that is, writing specific educational objectives but stating them in behavioral terms.

In this manner, student evaluation becomes much more valid, and the instructor has much more <u>tangible</u> evidence as to his effectiveness as a teacher. And finally, if the student is given a course syllabus, with its objectives stated in behavioral terms, on the first day of class the student will <u>know</u> what is expected of him, and <u>how</u> he is to be evaluated.

Communications of this sort are an absolute necessity if we are to instill confidence within the student, both of himself and the educational process, and from this confidence we can realistically anticipate that the student has been exposed to an educational process which will enable him to continue his education even after leaving the confines of a classroom.

COMPUTERS AND UNDERGRADUATE SCIENCE EDUCATION

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Introduction. The use of computers as a research tool and as an aid to problem solving has been familiar to a small group of scientists in our universities and colleges for many years now. However, recently several events have focused attention on the educational role of computers at the undergraduate level, especially in the sciences.

In February of 1967, the President's Science Advisory Committee, under the chairmanship of Dr. John R. Pierce, published its report "Computers in Higher Education", in which it was charged that an educational "computer-gap" exists. It was noted that in 1965 less than five percent of college students, "all located at a relatively few favored schools," had adequate computer service for their educational needs. Yet, the report estimated that more than a third of the students "are enrolled in curricula in which they could make valuable use of computers in a substantial fraction of their courses," forty percent will need computers for a significant portion of their educational programs and the remaining twenty-five percent could make a more limited use of computers in one or more of their courses. To close the gap, the panel recommended that steps be taken to provide every college student in the nation access to "computing service at least comparable in quality to that now available at the more pioneering schools" and to provide expanded faculty training in the use of computing in the various disciplines.

In his budget message to Congress on education on February 28, 1967, President Johnson noted the promise which computers may have for education. He said: "One educational resource holds exciting promise for America's classrooms: the electronic computer. Computers are already at work in educational institutions, primarily to assist the most advanced research. The computer can serve other educational purposes -- if we find ways to employ it effectively and economically and if we develop practical courses to teach students how to use it. I have directed the National Science Foundation, working with the U. S. Office of Education, to establish an experimental program for developing the potential of computers in education."

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Thus, on July 1, 1967, a new Office of Computing Activities was created within the National Science Foundation to explore the role of computers in education as well as to help academic institutions provide adequate computing services to faculties and students and to strengthen and expand educational and research development in computer science.

Several other activities also herald the new interest in the role of computers in education. The National Academy of Sciences has formed a committee on the educational uses of computers within the recently established Computer Science and Engineering Board. A newly formed committee on Computers in Chemistry within the National Research Council is now actively concerned with the educational uses of computers in chemistry. Many of the college commissions have expanded their activities with regard to the role of computers in the undergraduate curricula.

Why Computers? The question might easily be asked, Why the special emphasis on computers? This is not the first time educators have been told that some innovation holds great promise for the teaching of their subject. We are all familiar with the fanfare which surrounded the introduction of slide projectors, movies, film loops, programmed instruction, teaching machines, etc. -- and, yes, even the new science curricula. Yet, after years of use in our colleges and schools, many educators feel that these innovations never lived up to their advance billing. Isn't the computer just another technological aid in the long list of instructional media? Won't things return to "normal" once the novelty of this new gadget wears off?

The answer to these two questions is a simple no. However, much depends on you, the science educator, as well as the college administrators and computer scientists, and how much effort -- both financial and intellectual -- is given to exploiting the full potential of the computer for education uses. The question is no longer whether the computer is important for education, but rather how will the computer be utilized in education?

To better understand why the special emphasis on computers in education, a brief (and somewhat elementary) description of the computer follows.

Basically, a computer is a device which can perform arithmetic operations at very high speed, can perform a sequence of instructions, and make decisions to alter its own instructions as a consequence of some intermediate result in a computation in accordance with precise rules, called a program, laid down by its user. Very simply, the computer accepts information in one form and delivers it in an altered form.

The computer is capable of storing, retrieving, processing, disseminating, and creating information. The processes of storing, retrieving, processing, disseminating, and creating information are fundamental to education. Thus, the problem of major concern is how to match and utilize the computer with the processes of education.

It is as a tool of instruction that the computer holds so much potential. Much needs to be done to explore the use of computers to change the student's role in learning from one of a passive receiver of information to that of an active creator of information. Computer-based simulations are only now beginning to be proved to be a valuable teaching tool. Computer-based education permits a dialogue between the computer and the student which will permit the student to invent models, interact with a realistic data source, check hypotheses, make decisions, alter conditions, etc., while receiving immediate feedback.

The ability of the computer to manage educational processes holds the promise of individualized instruction in mass education. A student may be a more active participant, not only in the learning process, but in managing the rate at which he learns.

The role of a teacher may also change as he functions less as a source of information. He will be a manager of learning, of curriculum and technological resources to facilitate self-instruction of each student, as well as a manager of information sources.

The computer can also serve the institution as an information system which will collect, store and process data for the use of administrators, teachers, students, curriculum developers, specialists and counselors.

Office of Computing Activities. During the past fiscal year the Office of Computing Activities made 104 grants at a total of about $8.7 million to explore the role of computers in education, most of which have implications for undergraduate science education. In addition, 27 grants (about $2.7 million) for the support of R & D in computer science and 42 grants (about $10.6 million) for the support of computer facilities and services were made by the Office. A brief review of a few of the grants made by the Office may give a better idea of the potential of the computer for undergraduate education, especially in science and mathematics.

Of the 104 grants, eight projects will develop instructional materials for undergraduate science and mathematics courses. For example, Brown University's Dr. Davis will develop curricular materials and relevant computer programs such that the computer will be used as an integral part of the first course in calculus. Dr. Harbaugh of Stanford University is working on a project in which dynamic simulation models in a time-shared computer system with remote terminals in the laboratories will be used to illustrate principles of geology to non-science majors. A project at the University of North Carolina under Dr. Nicholson aims to integrate computers into the curriculum of undergraduate statistics courses and to develop curricular materials, sample data sets and instructional methods which utilize the potential of computers.

Four projects provided for the development of software and hardware facilities for education in mathematics, science and engineering. An example is a grant to Dr. Schwartz of M.I.T. for a project which will provide a regional facility for computer generated movies to be used for instructional purposes in the sciences.

A project under Dr. Burris at the University of Minnesota is directed toward a more thorough understanding of the teaching and learning processes in order to make effective use of the computer in teaching and learning, especially computer-assisted instruction.

The possible use of computer-assisted instruction to provide tutorial, simulation and drill-practice for remedial work to entering college freshmen will be investigated under a project to Tennessee A & I State University under Dr. Chapdelaine. This project will be tied into the Stanford CAI Center under Dr. Suppes.

Colgate University has a project to initiate computer science cultures in the various disciplines. Under the project faculty and students will be trained in the use of computers, and course material to integrate the computer into the undergraduate curriculum will be developed. An evaluation will be undertaken to determine the role of computers and computer science programs in a small liberal arts college.

Dr. Harris and Dr. Culler of the University of California, Santa Barbara, have begun a study of the pedagogic utility of on-line computers for chemistry education as the initial stage in a curriculum development project in chemistry. The project will use the Culler-Fried System and eventually involve six to ten chemistry departments from across the nation.

In December of 1967, the Office of Computing Activities convened a number of professors of mathematics, physics, chemistry, and statistics to consider the implications of computers for undergraduate instruction. The independent conclusions of the four panels, while specific to their disciplines, have a common message for all of undergraduate science education. The computer permits the student to do realistic problems as instruction examples which could bring him to the forefront of his field while still an undergraduate. The ability to program a computer to operate in a simulation or gaming mode of a real-life situation permits the student to manipulate a complex situation so as to gain insights into the underlying scientific or mathematical principles.

The use of computers in gaming or simulation is only now beginning to change the teaching of these subjects and needs to be more fully explored. Not only was it felt by the panelists that computers have changed the very nature of the solution process in mathematics and the sciences, but that a host of new concepts are opened up to the students. In addition, since the use of a highly interactive computive system allows the student to explore exercises which evolve naturally under his control, for many students the computer can turn the all-too-often passive college experience into one of active participation. (The recommendations of the conference will be published by the University of Maryland).

Of special importance for science education at the undergraduate level are the regional computer experiments which were initiated by the Office of Computing Activities during the past fiscal year. Partial support is provided for ten regional computing centers, which involve nine universities, 79 participating colleges and junior colleges, and 23 secondary schools. Within each group one institution--generally a major university--will: (1) serve as a regional computing center to the group; (2) work with the other members of its group to develop computer-oriented curricula, especially in the undergraduate science area; and (3) train faculty and teachers of its own and member institutions in the use of computers in education.

Each of these regional groups will share a different form of computing service and each grouping will involve institutions with different educational characteristics. Some participating institutions will have computing services provided them for the first time, while others will be able to extend or expand existing services.

Especially important to this program is the cooperative development of curricular materials and computer programs, the sharing of instructional ideas and the learning about the ways the computer is used in the undergraduate courses in the center universities, as well as creating an opportunity for cooperative research activities. In a real sense the regional centers are miniature "networks for knowledge" in education which provide a framework for the interchange of scholars, teachers, and students, in addition to providing networks for computing services.

While almost all universities have computer facilities available for some type of educational use, only about one-third of the four-year colleges have such facilities, and an even smaller percent of junior colleges and community colleges have facilities. However, in most four-year colleges, junior colleges and community colleges the facility is not adequate for the educational purposes of the institution. In many cases the computer was obtained for administrative data processing or represents an obsolescent hand-me-down. Yet, regardless of size, all institutions of higher learning are striving to improve their computer services to better imbed these services in the educational process and to better train their faculty in its educational use. Most institutions, even without computers for educational purposes, are struggling with the problem of how and where to begin, which is dependent on and determined by the institution's size, character, location, and philosophy. The computer education problems of the small, isolated Southern institution differ from those of the large college in the California system or those of the private college in the Northeast with the high college density. Thus, it is not unexpected that different types of institutions may have different solutions to the problem.

The regional activities program is designed to identify issues, explore solutions, and help to develop models for other institutions. The issues are numerous:

(1) How are institutions to train and orient faculty?

(2) How are institutions to obtain curriculum material,--through individual efforts, shared efforts, commercial vendors, etc., and how does compatibility or lack of it affect the strategy of a region?

(3) What discipline areas will be more amenable to penetration by the computer? And not independently, what are the more facilitative languages and operating modes, and what form should the service take?

(4) What are the costs for various educational applications, and how do these vary with different forms of computing service?

(5) What organizational forms may institutions or groups of institutions develop to manage the computing services they require for education and to promote cooperative activities?

The ten regional activities are designed to begin to explore, test, and demonstrate solutions to these questions. (A list of the ten regional activities and participating institutions appears in a July 8, 1968 release, which may be obtained from the Office of Computing Activities.)

Concluding Remarks. Funding policies of the Federal government and institutions have, up to now at least, favored the development and operation of computer facilities for research. The same kind of financial commitment for educational computer facilities has not been made. In fact, institutions have not viewed computer facilities for educational purposes as necessary or as important as, say, library facilities. Yet it is going to take just such a commitment of about the same magnitude as for the library facility to operate a computer facility for educational and research purposes.

Regardless of the reasons for the present state of computing in our colleges and universities, however, the facts are that the present widespread and rapidly growing use of computers at universities has created and will continue to create a gap between institutions with a strong graduate program and research interest and institutions primarily devoted to undergraduate instruction, especially the junior colleges. It is also likely to aggravate the gap between the researchers and those college professors primarily responsible for undergraduate instruction.

Thus, a special burden is placed on the science educator. Whether through individual study, attendance at college teacher institutes, conferences or workshops, involvement in regional computing experiments, or locally organized cooperative training activities, the science educator must make himself knowledgeable about computing and how it interfaces with his discipline. Otherwise, by default the researchers will have the major say in the development of computer-oriented undergraduate science curricula.

As new developments take place in computer technology, we can, if we exert our options, be able to take a new look at science instruction, its objectives, purposes and methods. We have shown, in spite of a great deal of recent activity, relatively little innovation in recent years either in the ends or in the means of science education. Computer technology may help revitalize the thinking about undergraduate science instruction, if we, the people interested primarily in the undergraduate curricula, take an active role in the new developments with using computers in education. Nothing more is expected of the science educator than what he expects of his students--an open mind receptive to change, exploration and learning in a new area--the ability to question the status quo of the means and ends of what he teaches in science.

REFERENCES

The following references are for the novice who may wish to get started in learning more about computers in education.

Computers in Higher Education, Report of the President's Science Advisory Committee, U.S. Government Printing Office, Washington, D.C. 20402.

Computers on Campus, John Caffrey and Charles J. Mosmann, American Council on Education, Washington, D.C.

The Computer in American Education, Don D. Bushnell and Dwight W. Allen, John Wiley and Sons, Inc., N. Y.

Computer Science at State Universities and Land-Grant Colleges, Office of Institutional Research, National Association of State Universities and Land-Grant Colleges, Washington, D.C.

American Education, volume 3, number 10, November 1967, U.S. Government Printing Office, Washington, D.C. 20402. (Contains a special section on "Computers in Education".)

Uses of Computers in Mathematics, Physics, Chemistry and Statistics, to be published for Office of Computing Activities by Science Teaching Center, University of Maryland.

In September 1968, under the leadership of Dr. William Viavant, the University of Utah served as host of a conference on the role of computer technology in small colleges. The discussions in several of the workshops focused on the need for modifying the content and basic philosophy of many of the present undergraduate science courses and on the most effective way of implementing some of these changes. Also, questions concerning the type of computer facilities for various educational and service functions were discussed in detail. Proceedings of the Conference will be available later in the academic year. Write to: Dr. Viavant, Computer Science Department, University of Utah, Salt Lake City 84112, to be put on the mailing list for information concerning the report of the Conference.

The programs of the Office of Computing Activities are described in the brochure "Grants for Computing Activities". Inquiries may be addressed to:

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National Science Foundation
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CAN TELEVISION PROVOKE STUDENT INVOLVEMENT?

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Instructional television has been available to educators for some twenty years. During this time it has been used at all levels of instruction from the primary grades through college. The introduction of instructional television generally has not resulted in change in the manner of instruction. In the public schools television is used many times to allow the specialists to present information to the student that the classroom teacher, because of educational background or lack of facilities, cannot present. At the college level large enrollments in undergraduate courses have forced instructors to go to large lecture halls or television. The television presentation gives every student a "front row seat". Demonstrations, 35 mm. slides, film footage, closeups of samples or experiments, views through microscopes and animation are all at the disposal of the television instructor. Certainly the use of television has provided an effective vehicle for the presentation of material in the classroom.

The question must eventually be asked: Should college education do more than present information? In the public schools, particularly at the elementary level, teachers have long been concerned with the individual student. At the lower division college level the emphasis is on large group instruction with little or no concern with what should be done for the individual student. In most lower division college lecture classes, little student involvement takes place. The dialogue that does develop involves questions about the spelling of a word or the asking of the instructor to repeat or clarify something the student did not hear or understand. Television has removed even these few chances for contact from the grasp of the student. Testing, however, has shown that students perform just as well in television courses as they do in standard lecture courses. Evidently the chance to "ask questions" is compensated for by a more effective manner of presentation. The idea that instructional television takes away the opportunity for student participation, "the give and take" that supposedly characterizes the college environment is absurd, since this atmosphere is non-existent in lower division undergraduate classes.

"Elementary Geology" at the University of Arizona is one of several courses fulfilling the science requirement of various divisions of the University. The enrollment is approximately one thousand students per year. Instructional television was started five years ago as a possible means of improving the instruction. The television director, Mr. Terry Thure, and I became concerned with the failure of television to be something other than a method of presenting information. It was decided to develop the television lecture in such a way that we would have student involvement in the material being presented. This involvement would take many forms but some examples might be having the students make their own observations from the television lecture, have them collect data from an experiment or to interpret information they have just seen on the television screen.

The elementary geology course is designed to meet the general education goals of the divisions it serves. The success of such a course would be measured by how well it met these goals or objectives. It was decided to state the objectives in behavioral terms to enable the instructional staff to determine how successfully they were meeting the goals of the course.

A thirty minute segment will serve as an example of how the course is being developed. Much of what geologists do is concerned with interpreting the history of the earth. Students have had a great deal of trouble distinguishing between statements of observation and statements that are explanations of observations. It was decided that the first segment would be concerned with the development of these ideas and the following objectives were set forth.

GENERAL OBJECTIVES

At the end of this instruction the student will be able to:

1. Distinguish between statements of observations and statements that are explanations of observations.

2. Identify statements that are explanations of observations.

3. Identify those statements of explanations that account for stated observations and those that do not account for the stated observations.

These general objectives are developed in a lecture that is part of a series entitled "The Earth--Its Characteristics". The lecture is concerned with the information used to indicate the spherical nature of the earth. Standard topics such as the flat appearance of the earth, the disappearance of ships over the horizon, the moon eclipse and the changes in position of constellations are the subjects of the lecture. The problem of observations versus explanations of observations is introduced using the ideas about the earth from Babylonian, Hindu, and ancient Greek cultures.

The lecture then proceeds to a demonstration of the disappearance of a ship over the horizon and the manner of disappearance of a lighthouse as a ship leaves the port. The student has a response sheet at his table and is asked to check statements on the sheet that are observations. The statements are all concerned with the demonstration the student has just witnessed. Later on the student is asked to read a paragraph concerning a topic just discussed in the television presentation and to underline those portions of the paragraph that are explanations of the observations. At another period in the lecture, following a presentation of all observations concerning the shape of the earth, the student is shown a set of five statements and asked to check those statements supporting the observations they have just witnessed.

In addition to the general objectives certain "content" skills have been found to add measurably to the students success in other phases of the course. Some of these are also developed in the first television session and, stated in behavioral terms, are as follows:

CONTENT OBJECTIVES

At the end of this instruction the student will be able to:

1. Describe the shape of shadows cast by regular three dimensional objectives (cube, sphere, cylinder) regardless of the position of the light source.

2. Apply the rule that the line sight distance on a sphere increases as the radius of the sphere increases.

Tasks during the lecture are given to determine how successful the presentation has been in developing the objectives of the lesson.

The statement of the objectives and goals of the television session in behavioral terms not only tells the instructional staff how successful the session has been, but it enables the instructional staff to determine exactly what sort of instruction should take place during the small group discussion period that every student attends each week. With proper administration the student could be assigned to a session that is dealing with the material in which he has shown unacceptable performance. Ultimately a measuring instrument will be designed that will tell the instructional staff exactly how each student stands at the beginning of the course with regard to the objectives of the course. This will allow the student to be assigned only to those portions of the course in which he has not already demonstrated satisfactory performance.

This proper usage of television will enable the teacher to provide for individualization of instruction as the weaknesses of each student are considered and these needs are met. This will necessitate a departure from the usual methods of using television, in that the specific needs of the students must be considered. This need can be determined by some type of measuring instrument, feedback, discussion sessions, etc. Once the need is established, flexibility will be necessary in the length of the individual presentation, since it may be desirable to have one sequence lasting 10 minutes, another 50 minutes, and another 27 minutes. They must be developed so that a 30 second or a five minute break may occur whenever it is desirable for the student to demonstrate a performance. Materials must be developed for use by the student within the viewing room. Some presentations will be designed to develop the direction for the discussion session where the objectives of the lesson will be met. This presentation may involve his active participation in making observations and measurements of some physical phenomenon with the interpretation of the information taking place in the discussion session.

We must be prepared to state the objectives of our instruction in terms that indicate how we intend to present the instruction. Behavioral objectives used in this form outline exactly what we expect of the student and how we intend to decide how well we have met our instructional obligation to the student.

TOOTHPICKS AND EVOLUTION

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While lecturing on the topic of evolution in a general biology course, one is often confronted with the task of illustrating or demonstrating various facets of the evolutionary process. It is far from satisfactory to discuss adaptation and natural selection merely by elaborating on some examples of extinct species or the more recent observations of industrial melanism and the variations in the populations of peppered moths (Biston). I would like to describe a fairly simple exercise that lends itself well to illustrating and investigating the ideas of adaptation and natural selection and other biological concepts. This exercise requires full class participation and always results in a great deal of class discussion. It also can be used to provide data for an introduction to the use of statistical analysis in biology.

Previous to the time the class meets, an area of the campus lawn is marked off and within this area I stick a number of different colored toothpicks into the ground, level with the height of the grass. I usually use 50 each of red, yellow, green and blue toothpicks for a class of 30-40 students. When the students get to class, I describe their participation in this fashion:

> "You are a flock of birds and a certain area of the campus lawn has become infested with your favorite food -- toothpicks! You will fly to this area and using only your sharp eyes for searching (use of hands is forbidden in searching) you will find as much food as you can in five minutes and bring it back to the classroom."

I don't tell them how many toothpicks I've placed in the lawn nor do I tell them the colors of the toothpicks.

Upon their return to the classroom, I put the data on the board in the following catagories: numbers of various colors of toothpicks found--red, yellow, green or blue; total number of toothpicks found; number of birds (students) who found 10 or more toothpicks, 5-9 toothpicks, 2-4 toothpicks, etc... From these data a number of ideas can be discussed and developed. In my experience with this exercise in the two years, I've found that some of the green and blue toothpicks are not found during the search. This data can be used to discuss adaptation and protective coloration. Also you might ask the question, "If you could have used your hands in addition to your eyes in searching, do you think the results would have been different? From this question you will get to the topic of degrees of adaptation.

If you listen to the cackling of the birds during the searching process, you will hear someone shout, "Hey, there are also green ones," or you may hear the same expression about the blue toothpicks. Why doesn't anyone shout the same thing about the red or yellow toothpicks? Ask how many birds saw only red or yellow toothpicks until someone mentioned the green or blue ones. This can lead to a discussion of the process of observation and how this can be influenced (Prejudiced?) by previous knowledge.

With the data on the number of toothpicks found by each bird you can discuss the concept of "survival of the fittest" and if nutrition plays an important role in determining the breeding ability of these birds, you can discuss this idea in terms of "survival of the fittest" and future populations of toothpick birds. These data can also be used to jolt your indifferent or lazy students by pointing out their apparent inability to compete successfully in this activity. Why?--because they are lazy or indifferent or have bad eyesight? If these data are plotted as a distribution curve, you will find that in most cases it can lead to a discussion of normal distribution and the use of statistics in biological investigations.

I also do this exercise again in the spring after the grass has turned brown from the winter freeze. The results, of course, are different for now the yellow toothpicks and even the red ones are more difficult to find than the green or blue ones. I use the data gathered at this time, and compare it with the previous data gathered in the fall, to illustrate the idea that an adaptation is not necessarily a change in the organism, but that the organism may be better adapted because of a change in the environment. This inevitability leads to a discussion of development of resistance to antibiotics by bacteria.

These are some of the types of ideas and concepts which can become the subject of class discussions (not lectures) following student participation in an exercise which can easily be set up by the teacher with a minimum of time, effort and equipment.

MAN AND THE TWENTIETH CENTURY

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Guilford College is a small liberal arts college which like all colleges is interested in making available the best education for its students. The EducationalPolicies Committee, which is composed of both faculty and students, has studied this problem very carefully for the past several years and numerous changes in our curriculum have been made.

We have been very concerned about the science courses which all students in the school have been required to take. Since special physical science and biological science courses were offered at Guilford College for non-science students, we examined these courses carefully. Although they were good courses, students who came out of them seldom liked science better or had any greater appreciation of the problems of science and scientists than they had when they entered the course. Tests administered after students had finished these courses showed that their scientific literacy had been little increased. In other words, the student who had no particular love for science was not gaining much from our courses.

As a result of our studies of the basic science curriculum, we instituted the "concept" courses in science some three years ago. These concept courses were reported upon in some detail at the NSTA CONFERENCE ON ESTABLISHING GOALS FOR SCIENTIFIC LITERACY in Jacksonville, Florida, in November, 1967.* In short, let me say that the concept courses in chemistry, physics, geology, or astronomy attempt to do the following: (1) develop at least one particular principle of the science being studied in such depth that the student may appreciate to some extent the way in which scientists arrive at a "truth"; (2) show how the search for science is a continuing one. By the use of the scientific method in each course, develop in the student a sense of relevance of the scientific method to science and perhaps even to his own life; (4) Make available for a thorough study some tool which the scientist uses so that the student may gain some appreciation of the work of the scientist; (5) help the student to see the difference between science and technology as well as the interaction of the two; and (6) expose the student to some of the better classical literature in the field so that he may obtain some knowledgeable glimpse of the scientist and his work.

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* Steps Toward Scientific Literacy--A Report of College Level Conferences for Non-Science Majors 1967-68, Special Publication, National Science Teachers Association, Washington, D.C. 1968.

Our success with these courses has been a joy to us. One indication of the student interest in science has been a measure of the increase in students electing additional science courses with their free elective hours. The number has increased in both of the last two years. Although we have not collected data completely for this past year, we have studied the pre-registration records of all juniors and have found that forty percent of the juniors who were not science majors elected "concept" courses or other science courses to be taken during their senior year. This is a large increase over the data of three years ago. Although we did not collect the material three years ago for exactly the same purpose, it seems to be more than double the number who elected science courses then.

This past year our Educational Policies Committee studied a new approach to the college curriculum which resulted finally in the idea that the basic Guilford College curriculum, which is required of all students, should be problem-oriented and should deal with contemporary challenges and opportunities for man in his social, political, artistic, economic, and natural environments. The results of thinking along these lines led to a required "common experience" freshman course entitled "Man in the Twentieth Century". This twelve semester hour course will be a two-semester course and will use the "team teaching" approach. The course will confront students with some of the more fundamental moral, psychological, social, and environmental problems facing contemporary man. This approach is expected to stimulate the student to develop some enduring interest in and concern about man that will give meaning and direction to the remainder of his studies. The focus on man and his problems should encourage the student to view his educational experiences as an inquiry into the human condition, thereby making his study of religion, philosophy, history, and related subjects more relevant to his personal situation.

This course will be planned and conducted by a team of six to eight teachers from as many disciplines and their efforts will be coordinated by a person appointed to this task. Instruction will be by a variety of modes including lectures by team members, films, visiting speakers, debates, and so on as a part of the formal course. There will be small discussion groups and evaluation of students will be based principally upon frequently assigned papers. Independent study will be an integral part of the course.

"Man in the Twentieth Century I" (first semester) might be entitled "Man in Society". This semester's work will focus on man's identity and the moral, social, psychological, political, economic, religious and philosophical problems which confront him in the twentieth century. It is assumed that confrontation with human problems--four or five during the semester--will enable students to come to terms with ideas in a more meaningful and significant way. Though the specific detailed content of the course will be planned by members of the team, the following types of problems might be considered: (1) Mass Urbanized Society and Man's Alienation: (2) Religion and Modern Man; (3) Radicalism in Modern Politics; (4) Industrialization and the Quality of Human Life; (5) Man, War, Conscience; (6) The Role of Students in American Education; (7) Poverty in the Affluent Sooiety; (8) The Impact of Population Dynamics; and (9) The Scientific Method, Knowledge, and Inquiry about the Human Condition.

"Man in the Twentieth Century II" (second semester) which might be entitled "Man in His Environment" takes its cue somewhat from the words of Dr. Donald F. Hornig, science advisor to President Johnson, when he said, "The time has come to teach science as one of the humanities". This course will emphasize the scientific and technological aspects of modern man's existence. Moral, human, cultural, and related matters will be examined within the framework of the impact of science upon man's environment and upon man himself. The need for such an approach arises in large part from the fact that scientists today are specialists with interests focused along rather narrow technical lines. In turn, this condition has been generated partly because the graduate schools in which young scientists are trained no longer deal with the universal and philosophical implications of science for man. Thus science is not taught from the standpoint of its relationship to people in a particular time; and its philosophical, social, political, economic, and other ramifications often are ignored. If graduate students in science fail to understand how and why science pervades broadly the modern era of human endeavor, the same is even more true of undergraduates. The deficiency is proportionately more important for non-science students and, consequently, for most educated adults with the result that few of us really comprehend science and the ways in which it is changing culture and producing the ideas and knowledge that provide the direction for much of modern life.

Most persons who are students now will spend a large share of their lives in the twenty-first century. Yet the insight necessary to facilitate and even preserve life in that technologically advanced time is inadequate. Rather than being a unifying element capable of bringing together the diverse segments of human culture, science has become just another fragment. Specialists in science have tended to exclude non-specialists from their company, despite several realities: (1) much scientific work is financed publicly: (2) the results of science affect all of mankind; and (3) non-specialists are needed to help solve the problems which have been created by scientific advances.

In the proposed course, conducted by team members drawn from the sciences, the social sciences, and the humanities, the following types of problems would be considered: (1) Air, Water, and Noise Pollution; (2) Dangers of Radioactive Fallout from Nuclear Devices; (3) The Effects of Biodegradable Detergents, of Pesticides, and of Other Chemical Contaminants; (4) The Implication of Molecular and Cellular Biology and Manipulated Genetics. The Question of Eugenics. (5) Problems of the Quality and the Quantity of the Food Supply. (6) Conservation of Natural Resources; (7) Secrecy in Scientific Research and Scientifically Based Decision-Making. (8) The Magnitude of Nuclear Weapons and the Dimensions of Potential Nuclear Warfare. (9) Relationships between the Scientist and the Citizen. The Scientist as Citizen. (10) The Moral Implications of "Pure" and "Applied" Science. (11) The Role of the Scientist in Providing Public Information. (12) The Question of Scientism as a Non-Empirical Value System. (13) The Intricacies of Ecological Relationships. Symbiosis and Equilibrium; Invasion and Succession. (14) Relationships between the Natural Environment and that Created by Man. (15) The Impact of Darwin and the Movement Toward an Ecological Frame of Reference. (16) The Biological Capacity and Limitations of *Homo sapiens*.

The basic theme of the course should be ecology and especially the exploration of the human ecosystem. Ecology is a science that can tell man much about himself, but its complex vocabulary presents a genuine challenge in translation. Yet the concept *ecosystem* deals effectively with the series of transactions that occur between organisms and their setting, pointing up the great network of reciprocal influences. Therefore, because of the significance of this approach, the necessary translations will be worth making in the course. In the last analysis, the ecosystem is the scientist's most fruitful approach to the study of the interactions between man and his environment.

It is planned that this freshman course will replace part of the present science required in the Guilford College curriculum. Students will elect then in the second year a semester of laboratory science to acquaint them with aspects of science that might have been missed in the "humanities"- oriented course. They might elect one of the "concepts" courses now offered or even take a semester of one of the courses for science majors. Whichever direction they choose to go, we are hopeful that these changes in our curriculum will make more intelligent, more involved citizens of our students.

A CHALLENGE FOR COLLEGES AND UNIVERSITIES

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During the past fifteen years we have witnessed changes in the teaching of science on all levels of education, but especially in the secondary and elementary schools. We have moved from a didactic form of presentation, where an accumulation of factual material was of utmost importance, to the inquiry approach, where the student learns science by participating in various experiments. However, we find in a high percentage of schools science still being taught as a body of classified knowledge rather than an approach to problem solving or an association of facts culminating in a concept or a principle. These science courses, I'm sure, have changed and developed down through the years, but generally by updating existing material or simply adding new information without eliminating the old. The type of teaching in vogue still resulted in students memorizing encyclopedia lists of facts completely divorced from a development of an understanding of the nature of science. As Dr. Paul DeHart Hurda has remarked, "We have been so concerned with the answers the pupils give, that it is forgotten that science is more a verb than a noun".

How does one explain the hesitancy that many of these schools have in not changing their departure from traditional practices. The fault cannot be in the lack of suitable materials, for in the last decade the National Science Foundation and other groups interested in science education have developed a broad variety of instructional materials designed to present science in a way that embodies contemporary thought on educational processes. There are those who feel that this hesitancy can be explained by the fact that most of the new programs in science have been developed outside of the schools with the support of Federal Funds. Others object because universal implementation of these new materials would in effect establish a national curriculum. The real reason why there is a lag in the implementation of various new curricular materials is, I think, not the fact that they were born outside the usual delivery room, but rather because they represent a substantial departure from traditional instructional procedures in the schools. Put it bluntly, their pedagogical discomfort index is high.

If we are agreed that there has been a certain degree of hesitancy in adopting the new curricular materials and thus changing the methodology of teaching science, what is our role as university people? There are many avenues that can be followed which can help personnel of local schools understand what the alternatives are and at the same time bring about improvements in the current offerings. The better training of pre-service teachers is one approach. Our teacher education programs in many institutions do not reflect the changes which have been produced by curriculum innovators with the past decade. Not only are the teaching programs antiquated in many instances, but the fact that many college instructors do not usually have more than a superficial familiarity, if any, with the many new programs now becoming available is even more destructive. Science teacher training programs should be structured in such a fashion that the participant is fully cognizant of the purposes and characteristics of quality science curricula. Effective science teachers are not mere conveyors of information, but rather have their obligation to assist students to develop an understanding of concepts and hence, a deep insight into the subject being presented. Local school systems should be entitled to assume that science teachers newly graduated from colleges and universities are adequately acquainted with the philosophy, rationale, and methodology of new school science materials. They should be entitled to assume that there is no need for them to return to colleges and universities almost immediately to learn the pedagogical techniques in science, yet we find every year hundreds of these recently graduated teachers not fully capable of assuming their role in helping students understand the world around them. They appear to be insufficiently knowledgeable about their materials and how to handle them in the classroom because they have not had the opportunity to try such materials with children nor see others teaching these materials to children. I am not implying that students in teacher education should be prepared necessarily to teach a prescribed course in biology, physics, chemistry or elementary science, but rather that they be made aware of the underlying philosophy of modern day science courses and understand what is meant by the discovery approach, inquiry, the investigative approach and open-ended exercises. There is clear evidence from observing teaching techniques of recent graduates that some colleges and universities do not put enough stress upon recent and important developments in science education. I am not attempting to say that the curriculum materials coming on the market are new in the sense of having had no prior existence at best colleges, but we must admit that they do represent a departure from traditional practice.

Colleges and universities as well as their instructors have a responsibility to re-examine their courses carefully to be sure that they include modern day approaches. It is realized that it no longer is possible to know or include all of the available materials in a particular course, but on the other hand, faculty members must recognize that a future biology teacher, for example, may well be better off with a course in geology than a second course in genetics. That understanding systematics is important, but not a course in algae, fungi, bryophytes, etc.. To teach modern biology requires that the teacher have a broad integrated picture of contemporary biology. What is true of the teacher of biology is also true of all the teachers of other areas of science.

Another example of an approach whereby colleges and universities can assist in bringing about improvements in science instruction is by collaborating with school systems in such programs as the Cooperative College-School Science Program under the National Science Foundation. This program supports projects whereby school systems may be assisted in improving instructional programs in science and mathematics through cooperative undertakings with higher educational institutions. The impact of this type of collaboration can be very significant upon the school system, and at the same time, the cooperating colleges and universities gain insight and experience which may be reflected in their own programs, especially teacher training, and colleges and universities are the logical place for teachers and administrators to go when they need information about current efforts in curriculum development. Unless college faculty members step in to help and advise schools it is possible, even probable, that good materials and courses will be slowly degraded by unwise and unskilled usage.

The challenge to colleges and universities concerns the constructive action they can take in the advancement of science teaching in our schools.

1. The pre-service education of science teachers must now be imbued with the content, rationale, and philosophy of modern curricula in science.

2. Colleges and universities must play an important role in the re-training of science teachers and in guiding the introduction of new science materials so that their merit is not dissipated in the translation from development to use.